US009409337B2

(12) **United States Patent**
Kumar et al.

(10) **Patent No.: US 9,409,337 B2**
(45) **Date of Patent: Aug. 9, 2016**

(54) **POLYACRYLONITRILE/CELLULOSE NANO-STRUCTURE FIBERS**

(71) Applicants: **Satish Kumar**, Atlanta, GA (US); **Huibin Chang**, Atlanta, GA (US)

(72) Inventors: **Satish Kumar**, Atlanta, GA (US); **Huibin Chang**, Atlanta, GA (US)

(73) Assignee: **Georgia Tech Research Corporation**, Atlanta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 203 days.

(21) Appl. No.: **14/509,362**

(22) Filed: **Oct. 8, 2014**

(65) **Prior Publication Data**

US 2016/0016345 A1 Jan. 21, 2016

Related U.S. Application Data

(60) Provisional application No. 61/901,519, filed on Nov. 8, 2013, provisional application No. 61/903,048, filed on Nov. 12, 2013, provisional application No. 62/002,761, filed on May 23, 2014, provisional application No. 62/004,053, filed on May 28, 2014.

(51) **Int. Cl.**

B29C 47/00	(2006.01)
D01F 9/16	(2006.01)
D01F 6/54	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***B29C 47/0014*** (2013.01); ***D01F 6/54*** (2013.01); ***D01F 9/225*** (2013.01); *B29K 2001/00* (2013.01); *B29K 2033/20* (2013.01); *D01F 1/10* (2013.01); *D01F 6/18* (2013.01)

(58) **Field of Classification Search**

CPC D01F 6/54; D01F 9/225; D01F 1/10; D01F 6/18; B29C 47/0014; B29K 2033/20; B29K 2001/00

USPC 423/447.1–447.9

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,098,688 A 3/1992 Schimpf et al.
6,638,883 B2 10/2003 Gaffney et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 202117274 U 1/2012
CN 102660768 A 9/2012

(Continued)

OTHER PUBLICATIONS

Chae, et al., Carbon nanotube reinforced diameter polyacrylonitrile based carbon fiber, Composites Science and Technology 2009; 69: 406-413.*

(Continued)

Primary Examiner — Daniel C McCracken

(74) *Attorney, Agent, or Firm* — Bryan W. Bockhop; Bockhop Intellectual Property Law, LLC

(57) **ABSTRACT**

In a method of making a carbon fiber, polyacrylonitrile is dissolved into a first solvent, thereby generating a first solution. A plurality of cellulose nano-structures is dispersed in a second solvent, thereby generating a first suspension. The first suspension is mixed with the first solution, thereby generating a first mixture. The first mixture is spun so as to draw fibers from the first mixture. The fibers are stabilized and then the fibers are carbonized. A fiber includes an elongated carbonized polyacrylonitrile matrix. A plurality of carbonized cellulose nano-structures is in the carbonized polyacrylonitrile matrix.

16 Claims, 1 Drawing Sheet